Windows in the Ancient Martian Atmosphere

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Using data returned from NASA's Mars Reconnaissance Orbiter spacecraft and the Phoenix Lander, researchers associated with Johnson Space Center made several important discoveries that help the space agency understand the ancient climate of Mars and the fate of carbon dioxide in its atmosphere.

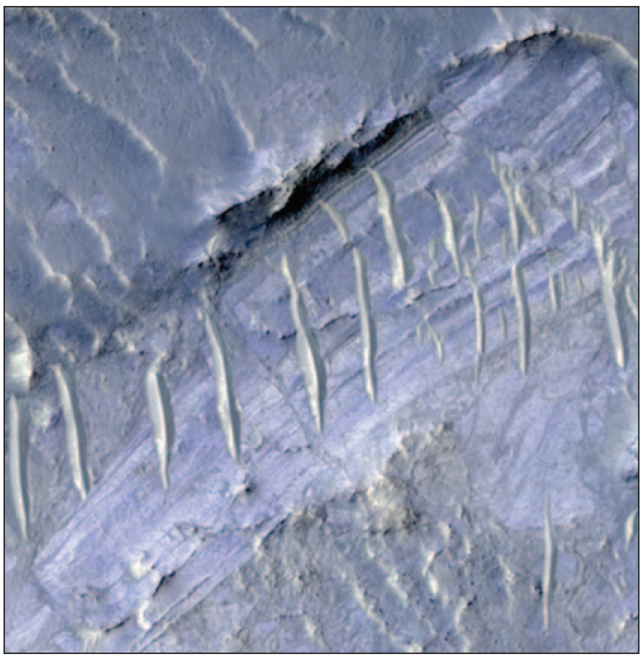

Fig. 1. *The central peak of Leighton crater—located at 57 E, 3 N—contains layered materials that have been uplifted from depth and tilted on end, displaying one of the best exposures of deep crust seen on Mars. Bedrock exposed in the uplifted central peak of the 65-kilometer crater contains clay minerals and carbonates suggesting hydrothermal alteration.*

A deposit of carbonate rocks that once existed 6 kilometers (km) below the surface of Mars was uplifted and exposed by an ancient meteor impact and has now been identified using the Compact Reconnaissance Imaging Spectrometer for Mars (figure 1). The carbonate minerals exist along with hydrated silicate minerals of a likely hydrothermal origin. Carbonate rocks have long been a Holy Grail of Mars exploration for several reasons: 1) carbonates form from liquid water on the surface and such deposits could indicate past seas that were once present on Mars; and 2) these minerals are the primary means for removing carbon dioxide (CO_2) from the atmosphere and abundant carbonates suggest that ancient Mars may have supported a denser CO_2 atmosphere with a much stronger greenhouse effect.

While this is not the first detection of carbonates on Mars, this particular detection is special because carbonates coexist along with hydrothermal silicate minerals, thereby indicating that a hydrothermal system existed in the presence of CO_2 deep in the Martian crust. This is exactly the type of environment that could be capable of sustaining microbiological life in the subsurface of Mars, which is protected from the harsh surface environment.

The Martian atmosphere is mainly composed of CO_2 and is less than 1% of the terrestrial atmosphere (figure 2). NASA's Mars Exploration Program has put a high priority on learning more about the history of the atmosphere on the planet, especially whether the modern atmosphere is a remnant of an older, thicker atmosphere or whether the modern atmosphere represents the conditions that have always been present on the planet.

Measurements of the isotope ratios in Martian CO_2 can address these questions, in addition to assisting in the discovery of ancient carbonate deposits. The Phoenix Lander made these measurements in the summer of 2008 with unprecedented precision. The measurements revealed that CO_2 on Mars has proportions of carbon and oxygen isotopes similar to CO_2 in Earth's atmosphere. This unexpected result reveals that Mars is a much more active planet than previously thought. In fact, results suggest that Mars has replenished its atmospheric CO_2 relatively recently, and that the CO_2 has reacted with liquid water present on the surface.

The low gravity and lack of a magnetic field on Mars mean that as CO_2 resides in the atmosphere, it will be lost to space—a process that favors loss of the lighter carbon-12 isotope compared to carbon-13. Although an older atmosphere on Mars should contain much more carbon-13, it doesn't. This suggests that the Martian atmosphere has been recently replenished with CO_2 emitted from volcanoes, and volcanism has been an active process in Mars' geologically recent past—within millions of years rather than billions.

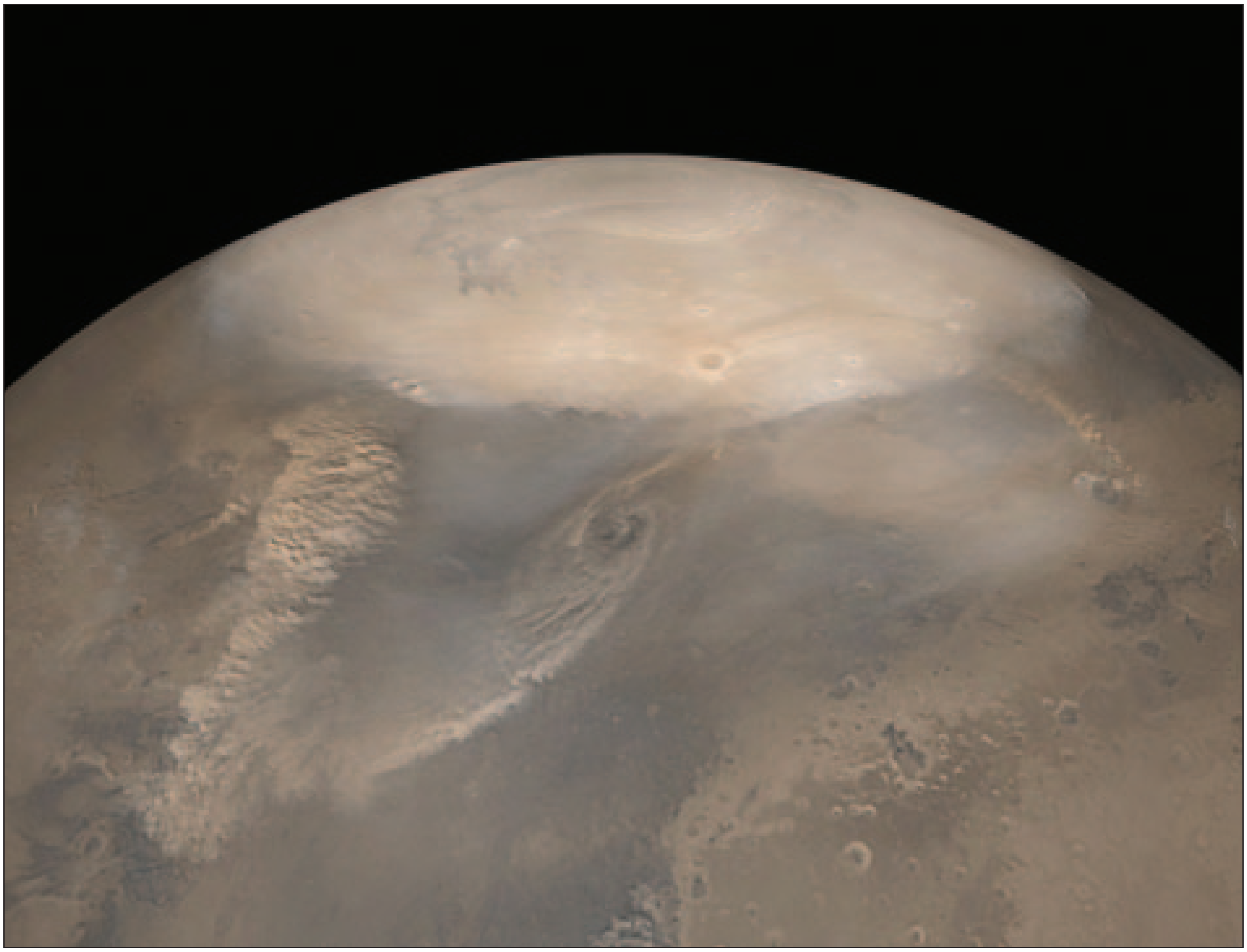

Fig. 2. *During spring on the Martian north pole, condensed carbon dioxide (CO_2) ice begins to thaw and return to the atmosphere. During Martian winter, as much as 25% of the atmospheric CO_2 can be frozen at one of the poles. This is a mosaic of images taken by the Mars Global Surveyor spacecraft in 2002. Credit: NASA/JPL/Malin Space Science Systems*

A volcanic signature is not present in the proportions of oxygen-18 and oxygen-16 in Martian CO_2, thereby suggesting that the CO_2 has reacted with liquid water, enriching the oxygen in CO_2 with heavier oxygen-18. These findings also suggest that the liquid water has primarily existed at temperatures near freezing, and that hydrothermal systems similar to Yellowstone National Park hot springs on Earth have been rare on Mars throughout its history. The findings do not reveal specific locations or dates of liquid water and volcanic vents, but geologically recent occurrences of those conditions provide the best explanations for the isotope proportions that were found.

The comparisons of the Phoenix Lander atmosphere measurements to measurements of Martian meteorites collected on Earth provide confirmation of key findings. The meteorites contain carbonate minerals similar to those detected from orbit. Certain meteorites contain carbonates with isotopic proportions that match the atmospheric measurements by the Phoenix Lander. This provides supporting evidence that the watery conditions associated with carbonate formation have continued even under Mars' current cold and dry conditions.